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INTERRELATIONSHIPS OF MILK YIELD, MILK COMPOSITION, AND CALF GROWTH

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Interrelationships of Milk Yield, Milk Composition, and Calf Growth" submitted by Vernon Martin Gleddie, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Forty-two beef cows composed of six breed-age groups were milked four times during their lactation to establish production levels, constituent percentages, and lactation trends. Fourteen additional cows of the same breed-age groups, and calving a month earlier, were milked to estimate the persistency of lactation trends. Milking was done by machine with the use of oxytocin. A 12-hour milk yield of one-half of the udder was multiplied by four for a 24-hour yield estimate. Milk was analyzed for butterfat, protein, solids-not-fat, and total solids. Calf milk consumption was measured in the first month.

Breed-age group averages for 24-hour milk yield ranged from 8.2 to 18.5 pounds with a herd average of 14.2 pounds. The beef cows showed a decline in milk yield from the first to the fifth month, which is different from dairy cattle lactation trends where a rise normally occurs from the first to the second month. The difference was probably due to the effect of calf suckling. In the first month of lactation, milk production was generally in excess of the calf's capacity to consume, and there was a physiological restriction to increased production. However, in those breed-age groups where the calves were found to consume all the milk available in the first month, milk production did increase to the second month.

Lactation averages for butterfat, protein, solids-not-fat, and total solids were 3.9, 3.5, 9.1, and 13.0 per cent, respectively. Butterfat increased from the beginning; very sharply toward the end. Other constituents decreased to the second month and then increased. Data from the 14 cows indicated a continuation in the rise of butterfat and total

solids and a levelling-off in the rise of protein and solids-not-fat percentages.

An analysis of variance showed that breed of dam contributed significantly ($P < 0.01$) to variation in milk yield, but sex of calf did not affect milk yield. The component of variance for breed of dam was 74.5 per cent.

Low, negative correlations indicated that the cows with the highest milk yields and producing the heaviest calves tended to lose the most weight over the summer. Day of lactation at first test, milking ease, cow weight and sex, and birth weight of calf were not found to be significantly correlated to milk yield or constituent percentages.

Any single milk recording was found to be highly correlated with any other and with the total of the four recordings. The highest relationship between milk yield and average daily gain occurred within the second month of lactation. Single or combination milk yield estimates were highly related to average daily gain from birth to weaning with correlation coefficients from 0.81 to 0.85, with one exception. The correlations between average daily gain and milk constituent percentages were generally low and non-significant.

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INTRODUCTION

The importance of milk yield in beef cattle production is through its influence on the growth of the nursing calf. An initial proposal for progeny testing of beef cattle included measuring milk consumption in order to measure efficiency of feed utilization in the suckling period (Sheets, 1932). However, because of the difficulty of measuring milk production as well as insufficient knowledge of its relationship to calf growth, it has not been included in progeny testing schemes for beef cattle. It is possible that selection for increased weaning weight in calves could be brought about more effectively by emphasis on milk production in the cow rather than by direct measurement of weight gains in the calf. Before this can be recommended, however, more knowledge is needed with regard to the exact nature of the interrelationships among milk yield, milk composition, and calf growth; also, the genetic and environmental complexity involved in these relationships should be sorted out. Related problems would involve determining the best method of measuring milk production and composition and the estimation of the influence of the calf's appetite on milk production and composition. It is to these ends that the current project was undertaken.

LITERATURE REVIEW

I. Levels of Milk Yield and Composition, and Interrelationships

Dairy breed averages of milk yield in the United States in 1960 were reported to range from 8057 to 12,392 lb. with an individual record reported at 42,800 lb. (Porter et al., 1965). Average percentages of constituents for major dairy breeds were listed by Morrison (1959) as follows: butterfat, 3.45 to 5.37%; protein, 3.30 to 3.90%; and total solids (TS), 12.32 to 14.86% (Table 1).

Table 1. Breed milk constituent averages

Breed	TS %	Fat %	Protein %	Lactose %	Mineral %
Ayrshire	13.05	4.05	3.51	4.81	0.68
Brown Swiss	13.13	3.97	3.52	4.90	0.74
Guernsey	14.51	4.90	3.90	4.97	0.74
Holstein	12.32	3.45	3.30	4.89	0.68
Jersey	14.86	5.37	3.79	5.00	0.70
Shorthorn	12.57	3.63	3.32	4.89	0.73

Source: Morrison, F. B. (1959)

In contrast to dairy cow milk yield, beef cow milk yield, as summarized in Table 2, was very low. For a 180-day period, age-corrected milk yield was reported from 2160 lb. for Angus to 5599 lb. for Holstein (Cole, 1948). When the season recordings of several authors were converted to a 24-hr production figure, beef cow milk yield was as high as 17.2 lb.; dual purpose, 17.6 lb.; dairy-beef crossbreds, 25.0 lb.; and dairy cows in the same herds, 31.1 lb. Butterfat records of cows including beef, dairy, and crossbred cows, as reported by Cole (1948) ranged from 3.51 to 4.82% (Table 2).

Table 2. Beef cow milk yield

Author	Cows or lactations	Breed[4]	Period days	Milk lb.	Range of milk lb.	24-Hr milk mean	24-Hr milk range	Cow age	Fat %
Gifford (1949)		He	240				4.2 - 8.6		
Neville (1962)	135	He	240	2300	400 - 4200	9.6	1.7 - 17.5		
Walker (1963)	10	A	180	2160	1800 - 2521	12.0	10.0 - 14.0	heifer	
	10	He x A	180	2310	1654 - 3006	12.8	9.2 - 16.7	heifer	
	10	A x J	180	3120	2472 - 3721	17.3	13.7 - 20.7	heifer	
	10	A x Ho	180	2310	1776 - 2819	12.8	9.9 - 15.7	heifer	
Alexander (1962)	6 "lots"		180		1410 - 1818		7.8 - 10.1		
Furr and Nelson (1964)[1]	106	He					4.0 - 7.6	2 - 4 yr	
Dawson et al. (1960)[2]	11	Sh	245	4168		17.0			
	50	Sh	252	4432	3026 - 5527	17.6	12.0 - 21.9		3.98
	42	Sh	365	4862		13.3			3.94
Cole (1948)[3]	9	A	180	2517		11.3			4.23
	4	Je	180	4528		25.2			4.82
	4	F_1A x J	180	3157		17.5			4.37
	4	F_2A x J	180	3629		20.2			4.26
	6	Ho	180	5599		31.1			3.51
	9	A x Ho	180	4495		25.0			3.71
	8	Ho x A	180	3800		21.1			3.77
	17	F_1 avg	180	4168		23.2			3.73
	14	F_2 avg	180	3689		20.5			3.84
Cole (1933)	7	A	milked as dairy	3100		17.2			4.10

[1] First 3 months not recorded for 3 and 4-year olds. Figures are averages of the authors and include 2, 3, and 4-year olds; low figures from cows on low nutrition and high figures from cows on high nutrition.

[2] Cows in group of 42 milked as dairy.

[3] Fat corrected milk and age corrected; milked as dairy.

[4] He, Hereford; A, Angus; J, Jersey; Sh, Shorthorn; Ho, Holstein.

Phenotypic intercorrelations among dams and among their daughters between milk yield, protein, butterfat, solids-not-fat (SNF), lactose, and ash percentages were calculated by Robertson et al. (1956) (Table 3).

Table 3. Phenotypic intercorrelations of milk yield and constituent percentages within herds among dams and daughters

	Fat %	SNF %	Protein %	Lactose %	Ash %
Dams					
Yield	-.03	.10	-.03	.16	.00
Fat, %		.33	.37	.16	-.18
SNF, %			.77	.63	-.08
Protein, %				.10	.13
Lactose, %					-.35
Daughters (first lactation)					
Yield	-.14	-.18	-.26	.08	-.05
Fat, %		.40	.42	.11	-.03
SNF, %			.81	.50	.12
Protein, %				-.01	.09
Lactose, %					-.28

Source: Robertson et al. (1956)

Highest correlations were between protein and SNF (r=0.77 and 0.81), lactose and SNF (r=0.63 and 0.50), butterfat and protein (r=0.37 and 0.42), and between butterfat and SNF (r=0.33 and 0.40). Correlations between solid constituent percentages and milk yield were small and mainly negative. Some slightly higher correlations were reported by Longley and Rennie (1964) (Table 4). Phenotypic correlations between milk yield and pounds butterfat from 0.89 to 0.93 were found by Gowen (1924) and Tyler and Hyatt (1947). The less than 1.00 correlation between weights of milk and butterfat explains the negative correlation between milk yield and per cent butterfat. As milk yield increases, butterfat yield increases but at a slower rate.

Table 4. Phenotypic correlations[1] of constituent percentages

	TS %	SNF %	Protein %	Lactose %
Fat, %	.81 - .95	.37 - .59	.44 - .65	.24 - .04
TS, %		.81 - .84	.73 - .78	.13 - .63
SNF, %			.74 - .80	.24 - .75
Protein, %				-.16[2] - .33

[1]Variation among major dairy breeds.

[2]Negative.

Source: Longley and Rennie (1964)

Negative genetic correlations demonstrated that selecting for milk yield would result in a small decrease in percentage of all components but protein (Robertson et al., 1956) (Table 5). Genetic intercorrelations between butterfat, protein, and lactose percentages ranged from 0.37 to 0.94.

Table 5. Genetic intercorrelations[1] between milk and constituents

	Yield %	Fat %	SNF %	Protein %	Lactose %
Fat, %	-.01				
SNF, %	-.02	.46			
Protein, %	.22	.48	.94		
Lactose, %	-.16	.37	.67	.41	
Ash, %	-.10	-.42	-.32	-.10	-.86

[1]Using correlations between daughter and dam.

Source: Robertson et al. (1956)

Genetic correlations reported between milk yield and pounds butterfat were 0.71 (Touchberry, 1951) and 0.85 (Tyler and Hyatt, 1947). Therefore, selection for pounds of either milk or butterfat would result in a substantial

increase in the other.

II. Calf Growth Relationship to Milk Yield

Since, in the earliest stages of life, the calf is entirely dependent upon milk for food, it follows that the correlation between milk consumption and daily gain in the early stages would be very high. Brumby et al. (1963) found that the relationship was almost absolute. Doney and Munro (1962), considering lamb growth to 6 weeks to be entirely dependent upon milk, used daily gain of a lamb as an indication of its dam's milk yield. Correlation of early lamb growth to consumption was 0.90 (Burris and Baugus, 1955).

As the young increase in age they become less dependent upon milk as a source of energy, and the relationship between milk yield and gain of the young decreases. Gifford (1949) reported correlations between milk yield and calf gain of 0.60, 0.71, 0.52, and 0.35 during the 1st through the 4th months, respectively, with no significant correlations beyond 4 months. Howes et al. (1960) and Walker (1963) noted significant relationships between milk consumption and calf gain to the 3rd month. Owen (1957) reported a decreasing correlation between lamb gain from birth and milk consumption by 2-week periods as 0.87, 0.76, 0.51, 0.42, and 0.21; the final correlation being non-significant. A similar report was made by Wallace (1948). With pigs, correlations between average daily gain (ADG) and milk consumption varied from 0.64 in the 2nd week to 0.09 in the 7th week (Salmon-Legagneur and Aumaitre, 1962).

When correlations between milk yield and calf gain in cumulative periods from the first few weeks in length to the full period between birth and weaning are compared, there is little variation. Correlations reported were: 0.52, 0.66, 0.67, 0.65, and 0.60 for 1, 2, 4, 6, and 8 months

(Gifford, 1953); 0.58 and 0.69 for 4 and 8 months (Rollins and Guilbert, 1954); and 0.72, 0.65, 0.61, and 0.65, 0.63, and 0.49 for 3, 6, and 8 months for two different breeds (Anthony, 1959).

Lamb correlations were 0.87, 0.83, 0.80, 0.75, and 0.69 for 2, 4, 6, 8, and 10 weeks (Owen, 1957). Other single reports of correlations between milk yield and gain from birth to weaning were between 0.50 and 0.80 (Knapp and Black, 1941; Brumby et al., 1963; Koch, 1951; and Neville, 1962) with exceptional values of -.31 and 0.91 reported by Furr and Nelson (1964). Similar rangesin correlations were reported by Whiting et al. (1952) and Burris and Baugus (1955) for lambs. Donald (1939) divided litters of piglets in half and made exchanges between sows. Correlation of weight of foster piglet at exchange and weight 3 weeks later was 0.60 and for 8 weeks later was 0.35, demonstrating a marked influence of the milk consumed on growth.

III. Factors Related to Milk Yield and Composition

A. Environment

1) Stage of lactation

Waite et al. (1956) summarized the change in yield of milk and constituents over the lactation period of Ayrshires in Scotland. Seasonal effects were eliminated. Milk yield rose to a peak at 45 days and then declined gradually. Per cent lactose followed a similar pattern although the peak was shallower. Percentages of SNF and protein trends were the reverse, decreasing until 45 days with a subsequent rise. Percentages of TS and butterfat also dropped but continued to do so for 70 days followed by a rise. Longley and Rennie (1964), in disagreement with Waite et al. (1956), showed that with the major dairy breeds in Ontario the decrease in percentages of TS and butterfat continued to 70 and 105 days, and the low

per cent in butterfat in some cases was maintained until 135 days after which time it began to increase. Percentages protein and SNF declined for about 70 days and then increased. Gavin (1913) found that 57% of dairy cows reached maximum milk yield in the 1st month. When only the cows calving from April to November were considered, 67% reached peak milk yield in the 1st month. Eckles et al. (1951) reported average Holstein production to be the highest in the 2nd month — opposite to butterfat percentage.

Walker (1963) found that dairy-beef crossbred cows, tested by before-and-after-suckling weighings, peaked in milk yield at the 9th or 12th week, while beef cows' milk yield rose until the 7th week. Cole and Johansson (1948), milking test cows as dairy, found that Holstein, Angus, and F_1 of the cross all peaked in milk production near the end of 2 month's lactation. Percentages of fat and protein decreased and lactose increased until the end of the 3rd month.

It may be concluded that although dairy breeds can be expected to reach maximum dairy milk yield in the 2nd month of lactation, no such definite prediction can be made for beef cows.

2) Season and year

Waite et al. (1956) and Davis et al. (1947) have demonstrated a seasonal effect on milk yield and constituents. Varying inversely with milk yield were TS, fat, and protein percentages. Solids-not-fat percentages varied little, tending to follow milk yield trends.

Cows that calve in the winter have the advantage of a boost in milk yield from the flushing of new spring pasture. Clark et al. (1958) reported that drought conditions had a marked effect on Hereford milk production. Brown (1960) noted that calves born in the fall were lighter than calves

born in the spring. Seasonal effect on milk production, however, has been shown to be primarily due to temperature fluctuation. Observations in the field were that as environmental temperature increased or decreased, there was an opposite change in percentages of butterfat and TS (Davis et al., 1947; Turner, 1936; Heinemann, 1930; and Becker and Arnold, 1935). Similar results have been obtained using psychrometric laboratories where temperature and humidity were regulated (Cobble et al., 1951 and Regan and Richardson, 1938). Since beef cows in any one herd are generally under the same seasonal conditions, that factor should have little relation to within-herd milk production variation.

Of much greater importance is effect of year of lactation. Wide variations in weaning weights of beef calves have been noticed from year to year (Burgess et al., 1954; Clark et al., 1958; and Brown, 1960). Neville's (1962) observation was that of 120-day and 240-day weights, and 240-day gains, only 120-day weights were influenced by year effects. The seasonal, nutritional, and management differences from year to year would contribute to year differences in herd milk production.

3) Pregnancy

It has been found that pregnancy does not appreciably affect lactation until at least 5 months after conception (Gaines and Davidson, 1926; Sanders, 1927; Erb et al., 1952; and Ragsdale et al., 1924).

4) Age of cow

Dairy cow milk yield has been found to increase until the fourth or fifth lactation, and remain high until the ninth lactation (Lush and Shrode, 1950 and Waite et al., 1956). The content by percentage of chemical constituents was found to decrease with age increase, protein the least and butterfat the most (Robertson et al., 1956 and Wilcox et al., 1959). Gifford (1949, 1953) observed that maximum milk production for

Hereford cows was attained at 6 years of age. Drewry et al. (1959) also found older beef cows to be heavier milkers. Weaning weights of successive calves from a cow were found to increase with her age to 4 or 5 years of age. Further slight increases were reported until age 7 or 8, and after that time weaning weight was found to level off to about age 10 years (Brown, 1960; Clark et al., 1958; Knapp et al., 1942; Lasley et al., 1961; Drewry et al., 1959; Rollins and Guilbert, 1954; and McCormick et al., 1956). Burgess et al (1954) reported that weaning weights of calves increased with dam's age through 8 years and then declined. From the majority of findings, the conclusion may be drawn that milk yield reaches its maximum soon after maturity of the cow and remains relatively constant until about 10 years of age.

5) Nutrition of cow

As nutritional treatments improved, milk production was found to increase (Anthony et al., 1959; Alexander, 1962; and Knapp et al., 1942). Of pairs of identical Jersey twins, the fattened member failed to milk as much as the normal-fed twin, as reported by Swanson and Spann (1954). In another experiment where one twin was under-fed and the other well-fed, the under-fed milked less (Flux, 1950). The apparent discrepancy in results of these two experiments may be explained by the fact that the optimum nutritional treatment for maximum milk production is not necessarily the diet of highest energy. As nutritional treatments improved for a Hereford herd (Neville, 1962), additional milk was required to produce a pound of calf gain. Drewry et al. (1959) observed that calves from higher-producing cows made the least gain per given volume of milk.

6) Size and weight of cow

There is some disagreement in the literature as to the relation

between cow weight and milk yield or offspring gain. Miller and McGilliard (1959) reported a dairy intra-herd partial regression of 200 lb. of milk per 100 lb. of weight at first calving. The significant regression of milk on weight at first calving must be qualified since age at first calving varies and relation of yield to age up to maturity is high. Other workers with dairy cattle found no relation between milk yield and cow weight, although wither height was genetically correlated to milk yield (Blackmore et al., 1958 and Mason et al., 1957).

Burris and Baugus (1955), Owen (1957), and Wallace (1948), in disagreement with Coombe et al., (1960) found ewe weight to be correlated to milk yield (r=0.56 to 0.75). However, when Owen (1957) removed the effect of milk yield on lamb growth by multiple regression analysis, there remained little effect of ewe weight on lamb growth.

Calf weight and gain have been found to have slight or no correlation to cow weight (Brinks et al., 1962; Clark et al., 1958 (Table 6); and Knapp et al., 1942). Calf gain was reported to be low and negatively correlated to cow weight changes over lactation by Brinks et al. (1962) (r=-.22 and -.17) and Gregory et al. (1950) (r=-.12 and -.34).

Table 6. Correlations between cow weights and weight changes over lactation to weaning weight and gain of calf for Herefords

	180-Day gain[1]	Weaning wt[1]	Gain, birth-weaning[2]	Weaning wt[2]
Previous fall wt (PFW)	.08	.12	.11**	.07*
Spring wt (SW)	.16	.21	.20**	.15**
SW - PFW	.17	.14		
FW - SW	-.22	-.17		
Fall wt (FW)	.05	.09		

*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

[1]Brinks et al. (1962).

[2]Clark et al. (1958).

Although there is little evidence for direct influence of cow weight on calf gain, there is reason to believe cow size is related to milk yield which in turn influences calf weight. The cow which is larger in size tends to produce more milk, and the cow which produces more milk tends to lose more weight over the lactation period.

7) Sex of calf

Significant differences between sexes were reported for calf birth weight, gain, and weaning weight (Lasley et al., 1961; Rollins and Guilbert, 1954; Koch and Clark, 1955b; Neville, 1962; Clark et al., 1958; Tyler et al., 1947; Koch, 1951; Botkin and Whatley, 1953; Brinks et al., 1961; Knapp et al., 1942; and Burgess et al., 1954). Brown (1960) noted that sex differences at weaning decreased with improved levels of nutrition, or in other words the sex difference was in the ability to thrive under sub-optimal conditions. In experiments conducted by Knapp and Black (1941), nursing bull calves consumed significantly more milk than steer calves but not so for hay and grain. It was suggested that superior beef qualities of bulls saved for breeding were due to the quantity of milk consumed. Sex differences in weight were found to be significant by Knapp and Black (1941) but differences between sires was not significant, indicating that there may be contribution to differences in calf growth attributable to sex outside of that due to weight alone.

8) Birth weight of calf

Birth weight of calf was found to be correlated to calf weaning weight and gain by Koch and Clark (1955a), Gregory et al. (1950) (Table 7), and Krasnov and Pak (1937). Howes et al. (1960), in agreement with Drewry et al. (1959), Neville (1962), and Knapp et al. (1942), reported that the heaviest cows produced calves of heaviest birth weight which grew faster.

Table 7. Genetic, phenotypic and environmental correlations between birth weight and weaning weight, and calf gain

Birth wt	Weaning wt[1]	Gain (b-w)[1]	Gain (b-w)[2]	Weaning wt[2]
Genetic	.63	.46		
Environmental	.29	.12		
Phenotypic	.39	.21	.07 - .44	.27 - .60

[1]Koch and Clark (1955a).

[2]Gregory et al. (1950).

Contrary observations were made by Koch (1951) and Botkin and Whatley (1953). Brumby et al. (1963), in finding no correlation between birth weight and milk consumption, suggested the only relation between birth weight and milk yield has to do with appetite since birth weights of calves from 200 dairy cows were uncorrelated with production. The apparent disagreement in results of the various authors may be because of unaccounted-for confounding of birth weight with age of cow and cow weight (Koch and Clark, 1955a; McCormick et al., 1956; Dawson et al., 1947; Clark et al., 1958; Knapp et al., 1942; Krasnov and Pak, 1937; Mason et al., 1957; and Coombe et al., 1960) in its relation to milk yield.

Coombe et al. (1960) found no relation between birth weight of lamb and ewe milk yield, suggesting that since there was a high correlation of both plane of nutrition during pregnancy and size of ewe with both birth weight of lamb and ewe milk yield, any relation between the latter was indirect. Owens (1957) reported that when the effect of milk yield was removed by multiple regression there was no relation between lamb birth weight and lamb growth, thus ewe weight and birth weight influenced growth because of a common relationship to milk yield.

9) Appetite of calf

There have been various observations indicating that milk

production of a beef cow may be controlled by the capacity of the calf for milk consumption. Gifford (1949, 1953) suggested that the reason beef cow milk yield declined from the initial stages of lactation was that calves were not able to cope with the amount of milk available to them. Daily calf milk consumption maximums were set arbitrarily by Gifford (1949) at 12 to 15 lb. and by Brumby et al. (1963) at 16 lb. Lactation and milk consumption averages equal to or much higher than these restrictions have been reported (Table 2, p. 3). In support of Gifford's theory, physiological studies have revealed that leaving milk in the udder means maximum secretion will not take place and resorption may occur if maximum udder capacity is reached (Petersen and Rigor, 1932). When milk consumption of twin and single lambs was compared within the same breed and flock, it was observed that milk produced by a ewe was a reflection of the number of lambs suckled, or in other words milk yield was controlled by the capacity of offspring suckling (Davies, 1963 and Alexander and Davies, 1959). Burris and Baugus (1955) made contrary observations but their studies involved only five sets of twins. Donald (1937a,b) reported that although there was no evidence that anterior nipples on a sow produced more milk at freshening, the larger piglets were found nursing anteriorly. The explanation was that the larger, more aggressive piglets, in order to escape the slashings of the sow's hind legs, managed to establish themselves in the favorable anterior positions. Since the larger piglets had a greater appetite, production through anterior nipples did not decrease as rapidly. These interpretations of Donald may be considered theoretical although they do in theory agree with the previously mentioned work with cattle and sheep.

B. Genetic factors

1) Breed of dam

Milk production varies with breed for both dairy and beef cows. Records of dairy and dairy-beef crossbred cows were higher than those for beef cows, and levels of production varied within beef breeds of cows (Table 2, p. 3). With beef cows, decline in milk yield was found to begin at about 7 weeks compared to 9 or 12 weeks for dairy or dairy-beef crossbred cows (Walker, 1963), all cows being in the same herd and tested by calf-consumption records. Breed differences indicate genetic variation.

2) Inbreeding

A decrease of 73 lb. of milk and 2.3 lb. of butterfat for every 1% increase in inbreeding of cow was reported by Tyler (1946) for Holstein-Friesians. For every 1% increase in inbreeding of dam there was a reported loss of 1.15 lb. weaning weight (Burgess et al., 1954) and a reduction of 0.22 $\pm$0.39 lb. weaning weight (Swiger et al., 1962) for Hereford calves.

A loss of 1.75 lb. weaning weight (Burgess et al., 1954) and 0.70 lb. weaning weight (Swiger et al., 1962) were reported per 1% increase in inbreeding of calf. Inbred calves had decreased food consumption (Swiger et al., 1962). Inbreeding will therefore result in both a decrease in milk of dam and milk consumption by calf.

3) Sire effect

No effect of sire on calf weights and gain to weaning was the report of Neville (1962), Knapp and Black (1941), and Gregory et al. (1950). Sire effect, as reported by Pahnish et al. (1961), Brown (1960), and Knapp et al. (1942) contributed from 5 to 15% of the variation in weaning weight of offspring. Brown (1960) further observed that in an Angus herd on a high plane of nutrition, sire effect was negligible, probably due to the

increased supply of milk masking other factors of growth. Brumby (1963) stated that because the correlation of milk yield and calf growth declined with increasing age of calf, the influence of sire on weaning weight increases as time of weaning is delayed. As dependence upon maternal environment decreases, sire contribution to genetic make-up manifests itself.

4) Heritabilities

Heritabilities of milk yield have been reported to be mainly near 0.30 but up to 0.60 (Table 8). Similar figures were reported for pounds of constituents. Per cent of constituent heritabilities have ranged from 0.30 to 0.80 (Table 8). Estimates of heritability of calf gain from birth to weaning range from 0 to 0.45 (Table 9). Similar figures exist for heritability of weaning weight with the mode at about 0.30 (Table 9). Although estimations of heritability of milk characteristics, especially weights, were more consistent, they nevertheless were about the same as those for weaning weight. Considerable response to selection for these traits can be expected. Genetic correlations between beef and milk characters were found to be very small by Mason (1964) and therefore selection for one should not result in appreciable change in the other.

Table 8. Heritability estimates of milk yield and constituents

Author	Milk yield	Fat yield	% Fat	lb. TS	% TS	lb. SNF	% SNF	lb. Protein	% Protein	Method
Johansson (1953)		.32 to .39	.54 to .68							dam-daughter correlation (r)
Robertson et al. (1956)	.25	.35					.50		.50	dam-daughter r
Johnson (1957)	.30	.30	.33	.34	.38	.35	.34			dam-daughter r
	.26	.33	.33	.37	.36	.34	.36			dam-daughter r
Duckwall (1963)	.32	.32	.59							dam-daughter r 1/2 sib r
Hancock (1954)		.95						.94 (casein)		twin data
Mason (1964)	.27		.48							paternal 1/2 sib r
Van Vleck and Bradford (1964)	.43									dam-daughter r
Mason et al. (1957)	.57		.84							between and within-sire analysis
Tyler and Hyatt (1947)	.31	.28	.55							dam-daughter r
Miller and McGilliard (1959)	.30 to .60									paternal 1/2 sib r
Pirchner (1962)		.54				.20		.37		dam-daughter and sire r

Table 9. Heritability estimates of calf growth

Author	Gain (b - w)	Weaning wt	Method[1]
Swiger et al. (1961)		.25	paternal 1/2 sib
Koch (1955a)		.24	paternal 1/2 sib
McCormick et al. (1956)		.30	paternal 1/2 sib
Dawson et al. (1954)		.00	paternal 1/2 sib and sire offspring
	.05 - .15	.05 - .15	dam offspring
Knapp and Clark (1950)		.28	1/2 sib
Tyler et al. (1948)		.20 - .35	dam-daughter and 1/2 sib
Swiger et al. (1962)[2]	.14 and -.02		paternal 1/2 sib
Lasley et al. (1961)	.03	.11	
Brinks et al. (1964)	.40	.43	paternal 1/2 sib
Gregory et al. (1950)	.45	.26 - .52	paternal 1/2 sib (two herds)

[1] Correlations.

[2] Heritability of gain, in two different herds, from birth to 130 days was -0.16 and 0.15 and from 130 days to weaning was 0.44 and 0.28.

5) Repeatabilities

Selection on the basis of one measurement is justified only when the correlation of succeeding measurements is significant. Repeatabilities of seasons' production have been reported as: milk yield, 0.52 (Rendel et al., 1957) and 0.46 (Mahadevan, 1951); fat, protein, and SNF content, 0.42 to 0.78 (Pirchner, 1962 and Johansson, 1953); per cent fat, 0.62 (Johansson, 1953); and per cent SNF, 0.60 (Wilcox et al., 1959). Repeatabilities of cows with respect to weaning weight of calves have been reported between 0.34 and 0.52 (Gregory et al., 1950; McCormick et al., 1956; Koch, 1951; Botkin and Whatley, 1953; Koger and Knox, 1947; and Koch and Clark, 1955a). Estimations of repeatabilities for gain from birth to weaning were all near 0.35 (Botkin and Whatley, 1953; Koch and Clark, 1955a; and Gregory et al., 1950) with the exception of 0.60 (Gregory et al., 1950).

IV. Methods of Measurement of Milk Yield

A. Calf before-and-after-suckling weighings

For reliable estimates of calf consumption, it is necessary to approximate the field situation. Therefore, the frequency of nursing is important. Observations of Drewry et al. (1959) were 4.6, 4.8, and 3.0 times suckled per day in the 1st, 3rd, and 6th months, respectively. Negligible suckling occurred in the night. From ten 24-hr observations on a herd over one lactation period, Walker (1962) noted that 84% of the calves suckled three to five times per day, and of those 34% suckled four times. From one 24-hr observation, Johnstone, Wallace and Kennedy (1944) found that calves suckled three times at 8-hr intervals. In practice, investigators used some variation of two or three sucklings at regular intervals to estimate 24-hr consumption (Furr and Nelson, 1964;

Drewry et al., 1959; Dawson et al., 1960; Neville, 1962; Knapp and Black, 1941; Gifford, 1949; and Walker, 1963).

With sheep, the most common number of sucklings used was four per 24 hr (Owen, 1957; Wallace, 1948; Davies, 1963; Burris and Baugus, 1955; Thomson and Thomson, 1953; and Whiting et al., 1952). Wallace (1948) showed that there was no difference in results from 2 and 4-hr intervals. Barber et al. (1955) observed significantly higher milk consumption from hourly suckling by piglets than from 2-hr intervals.

With cattle, no more or less than three to five sucklings in 24 hr are required to approach field conditions, however, the suckling technique at best only measures how much milk the calf consumes rather than the actual milk yield (Davies,1963; Coombe et al., 1960, McCance, 1959; Thomson and Thomson, 1953; Gifford, 1949 and 1953; and Drewry et al., 1959).

B. <u>Machine and hand-milking estimation</u>

Manual (machine and hand) milking techniques involve the use of oxytocin injection to stimulate milk let-down. Anthony et al. (1959) have described a procedure employing oxytocin to stimulate milk let-down in range cows.

The initial work to determine the nature of the effect of oxytocin was undertaken by Ely and Petersen (1940 and 1941). The left half of the udders of eight Jerseys were sympathectomized by removing a 2-inch portion of the ileo-inguinal and posterior inguinal nerves as they enter the gland in one trunk below the inguinal ring. These nerves were believed to supply the only efferent stimuli to the gland tissue. The theory advanced by Ely and Petersen (1941) was that palpation of the udder or some other conditioned reflex caused an efferent stimulus to travel to the hypothalamus, with a subsequent release of oxytocin into the blood from the

posterior pituitary gland. When oxytocin reaches the mammary gland, it is responsible for contraction of the alveolar and small ductile musculature resulting in ejection of milk and filling of the udder and teat cisterns. Oxytocin activity does not decline until 12 to 18 min after first effect (Whittlestone, 1962).

Ely and Petersen (1940) noticed that fright caused prompt cessation of milk ejection. Intra-jugular injections of epinephrin brought about the same reaction, and the larger the injection, the more time was required for resumption of milk ejection. Intra-jugular injections of posterior pituitary lobe fractions containing oxytocin caused a resumption of ejection within 30 sec. The authors theorized that adrenalin has an opposite effect to that of oxytocin, causing a relaxation of alveolar and ductile musculature. Similar findings were reported by Kullander (1963) although oxytocin infusion intravenously, following adrenalin injection, was found to be slower in resumption of effect than reported by Ely and Petersen. Donker et al. (1954) found that fright or excitement raised the threshold of oxytocin required to four times the 1.5 IU usual minimum to bring about milk let-down.

When manual methods are employed, the milking intervals which will give an accurate measure of lactating ability must be known. Intervals as unequal as 8 hr - 16 hr with dairy cows did not give significantly different production figures than equal intervals (Schmidt and Trimberger, 1963; McMeekan and Brumby, 1956; Koshi and Petersen, 1954; Linnerud et al., 1962; and Turner, 1955a). Turner (1955b) reported that any given interval between milkings had a similar effect at any stage of lactation. He also found that secretion was constant up to 20 hr if

oxytocin was used to remove residual milk at the previous milking. McMeekan and Brumby (1956) reported milk secretion to be constant up to 20 to 24 hr. A figure of 12 hr was given by Turner (1962). Long-term, regular use of oxytocin resulted in increased milk and fat output in dairy cows according to Sprain et al. (1952). It may be concluded that testing at up to a 12-hr interval will give an accurate estimate of milk yield.

C. Comparison of calf consumption and manual methods of estimating milk yield

Coombe et al. (1960), estimating milk yield by the suckling method from lamb weighings every 5 hr and by the manual method using oxytocin in a 2-hr interval test, found that manually obtained milk yields were consistently higher for the lactation period of ewes. The authors attributed the low milk yield realized in the lamb-suckling method to excessive handling techniques inhibiting normal milk let-down. It was further suggested that since the lamb-suckling technique left more milk in the udder than oxytocin methods, extensive use of it may have resulted in over-all depression of lactating ability. Use of oxytocin, on the other hand, because it allowed for complete emptying of the udder, may not have simulated field conditions. The manual method was preferred as most convenient and also dependable because upset of the ewe did not interfere with milk ejection. McCance (1959), whose results agreed with the foregoing, felt that manual estimates were no serious departure from what might be expected in the field. Since manual methods of milking with the use of oxytocin can be controlled more than the suckling and weighing methods, and is closer to estimating actual milk yield, it is the superior method. If appetite of calf actually regulates dam's milk yield, then oxytocin-

stimulated milkings, as an estimate of milk yield, should accurately measure calf consumption after the first few weeks.

D. Recording frequency

Bimonthly recordings were reported to give no significantly different results in predicting seasons' milk production than monthly recordings (Van Vleck and Henderson, 1961; Nagy, 1960; Czakó et al., 1962; Stichbury, 1957; and Amble and Rajagopalan, 1960). Jardin et al. (1956), however, found that bimonthly recordings gave significantly different results than monthly ones. Bimonthly records were labeled "too inaccurate for practical use" by Patchell (1954-55), but in another study Patchell determined that three testings, in the 10th, 18th, and 26th weeks of lactation, were as accurate in predicting total yield as monthly tests. He further suggested that only three measures per year for percentage SNF were highly accurate in predicting average season percentage. Neville (1962) found that only two or three samplings per lactation were necessary to determine calf consumption.

EXPERIMENTAL

I. Objectives

The current project was undertaken to determine:

a) the levels of range-cow milk yield, milk composition, and lactation trends;

b) the relation of breed of cow, sex and birth weight of calf, cow weight and weight change over the lactation period, stage of lactation, and ease of milking to milk yield and composition;

c) the effect upon calf growth of differences in dam's milk yield and composition; and

d) the accuracy of various numbers or intervals of recording in estimating milk and percentages of constituents of milk.

II. Materials and Methods

A. Source of data

The University of Alberta beef research herd was used for the present study. The breeding and general management of this herd has been described (Berg, 1962). Cows were selected which had calved in a 40-day period and within 45 days of the first test date. Included were five each of Hereford and Galloway x Angus 2-year-olds, eight Charolais x Angus (four 3-year olds and four 5-year-olds), and eight each of mature Hereford, Angus, and Galloway breeding. There were equal numbers of male and female calves in the experimental group and within each of the mature Hereford, Angus, and Galloway breed groups. All cows had calved the previous year except one Angus (64-9) and one Galloway (2-8). The 2-year-old heifers were calving for the first time.

An additional 14 cows representing all the above breed-age groups were selected for testing to obtain additional data on persistency of

lactation. They had calved about 1 month earlier than the main experimental group.

B. Milking procedure

Testing was done four times. The first test fell before the 45th day of lactation, or before the normally expected peak of milk yield, and the final one just preceded weaning. The distribution of four test days for each of 42 cows and two test days for each of 14 cows over their lactation is presented in Fig. 1. The dates of milking were June 8 to 11, July 6 to 9, August 25 to 27, and October 6 to 8, all in 1964. Hereafter they shall be referred to by month only or in relation to stage of lactation, i.e. 1st, 2nd, 4th, or 5th months, respectively.

The calves were removed from their dams the afternoon before test day. Each cow was restrained in a commercial stock squeeze and 1 ml of commercial preparation of oxytocin (20 IU) administered intrajugularly. A portable Surge (Babson Bros. Ltd.) milking machine was used and operated at 12 to 16 inches (of mercury) vacuum and 60 to 70 pulsations per min. Machine milking was followed by hand stripping to remove all the milk. The udder was examined for abnormalities. Following milking, cows were separated from their calves overnight and allowed access to feed and water. The following morning, 12 hr after the pre-milking, the procedure was repeated with the cows in the same sequence except that only one side of the udder was milked if the udder was normal. The milk was weighed for 12-hr yield and 8-oz samples were taken for chemical analyses. Two grains of commercial mercuric chloride preservative were added and all samples were refrigerated. Milk weighings were multiplied by four for estimating 24-hr yield. Two cows which had subfunctional or nonfunctional teats were milked from all normal teats and milk weight was multiplied by two for estimating 24-hr yield. The average milking and sampling time per cow was 6 min.

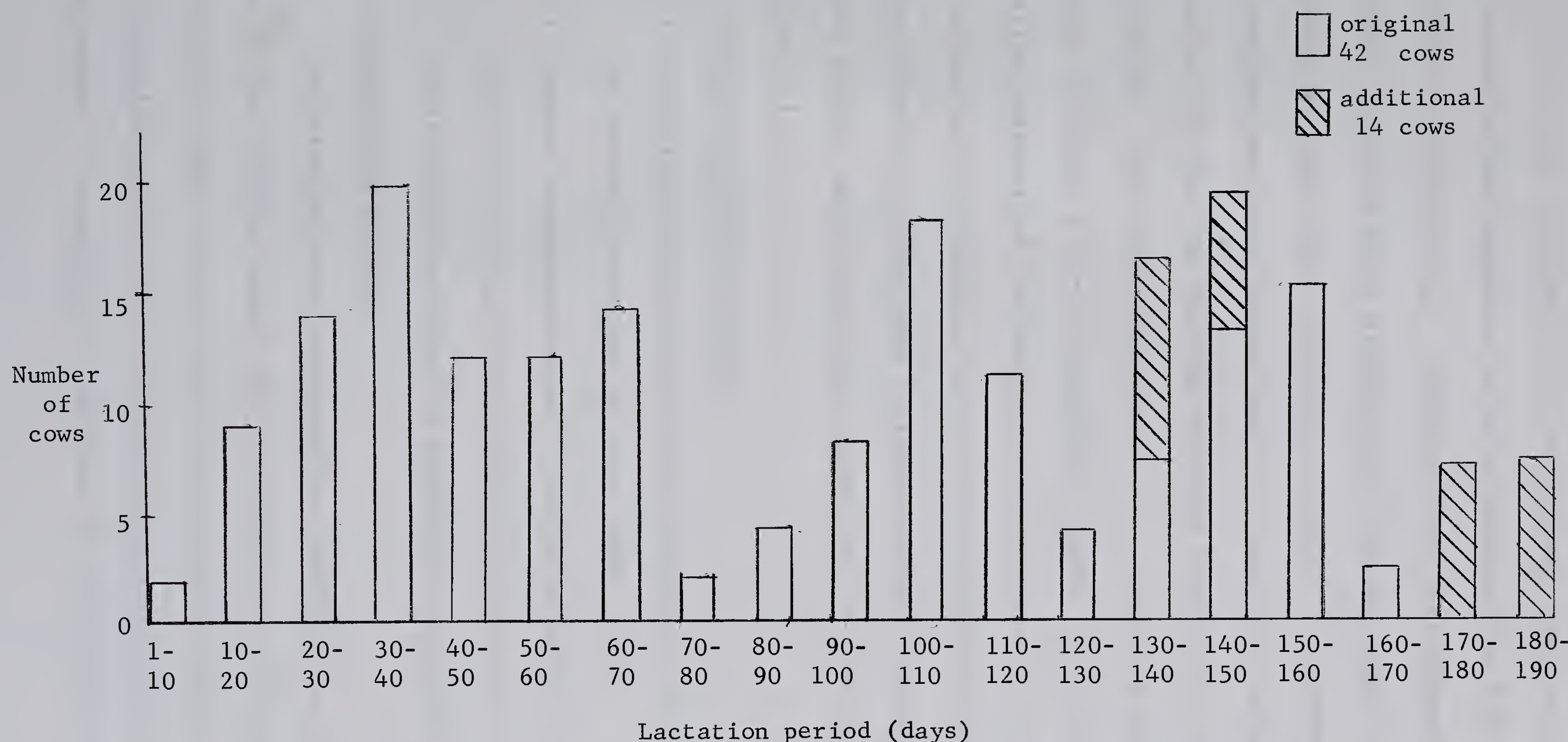

Fig. 1. Distribution of four recordings of the milk yield of 42 cows and two recordings of the milk yield of 14 cows by day of lactation.

C. Measurement of calf consumption

On the day following the June milking, the cows with their calves were corralled and separated in the afternoon. At 7:00 PM they were reunited to allow nursing. The calves were then separated from the cows overnight, the cows being allowed both feed and water. At 4:30 AM the following morning, calves in groups of eight to ten were allowed to nurse. Calf weights were noted before and after nursing. Calves were again separated from the cows and the procedure repeated at 10:00 AM, 3:00 PM, and 7:00 PM. Calf weight differences for the four sucklings were added together to obtain a 24-hr consumption figure. No differences due to urination, defecation, or robbing of milk from a cow other than the dam were accounted for; however, calves were separated from the cows as soon as the calves in a group were finished nursing. Calves whose consumption figures did not match their dam's milk yield in June were tested similarly on July 9.

D. Chemical analysis of milk

1) Butterfat test was done by the Provincial Dairy Testing Laboratory. The Babcock procedure was used (AOAC, 1960).

2) Protein determination was by macro-Kjeldahl procedure (AOAC, 1960).

3) Solids-not-fat was determined by subtraction of fat from TS.

4) Total solids was found by gravimetric procedure (AOAC, 1960).

E. Statistical analysis

Correlations were calculated to determine the relationship of rate of milk flow (milking ease), day of lactation at which first test was made (test day), weight of dam in March (cow weight), weight change of dam over her lactation period, and sex and birth weight of calf with milk yield and constituents. An analysis of variance in milk yield was done to estimate

breed and sex effects.

Multiple regressions by the method of least squares were used to estimate the effect of milk yield and percentages of butterfat, protein, SNF and TS on ADG of calf. In one regression analysis, milk yield was replaced by milk consumption. F-tests were used to determine the significances of the partial regressions. The mathematical model was as follows:

$Y_{ijklm} = \bar{u} + m_i + f_j + p_k + t_l + s_m + e_{ijklm}$, where

Y_{ijklm} is the value of the $ijklm^{th}$ calf for ADG

$\bar{u}$ = the effect common to all individuals

m_i= the effect common to all cows with i^{th} milk yield

f_j= the effect common to all cows with j^{th} per cent butterfat

p_k= the effect common to all cows with k^{th} per cent protein

s_l= the effect common to all cows with l^{th} per cent SNF

t_m= the effect common to all cows with m^{th} per cent TS

e_{ijklm} = a random effect due to error

Intercorrelations of milk yield, consumption, and constituents were used as measures of interrelationships among the variables.

The IBM 7040 computer, using University of Alberta Computing Centre program G2011 was used to calculate means, standard deviations, correlations, and multiple regressions. Calculations were done as outlined by Steel and Torrie (1960).

When the F-test is used, significance is designated by two asterisks corresponding to $P < 0.01$ or one asterisk indicating $P < 0.05$.

III. Results and Discussion

A. Milk yield levels and lactation trends

The range of individual 24-hr lactation averages for milk yield was from 6.0 to 22.0 lb., and 180-day records from 1064 to 3659 lb. (Table 10). For the whole group the 24-hr average milk yield was 14.2 lb. and 180-day average was 2515 lb. (Table 11). Breed-age group averages ranged from 8.2 lb. per 24 hr and 1458 lb. per 180 days for Hereford heifers to 18.5 lb. per 24 hr and 3292 lb. per 180 days for mature Angus. Angus, Galloway, and Charolais x Angus milk yields were equal or superior to milk yields of any beef and some dairy-beef crossbred cattle reported by other workers, whether records were obtained by calf-suckling or manual methods (Table 2, p. 3).

There was a decline in average daily milk yield from the first through the fourth test (Fig. 2; Table 11), contrasting with the peak in milk yield of dairy cows which is reported to occur at about 45 days lactation (Waite et al., 1956). Mean milk yields at each successive test were 16.9, 15.5, 13.3, and 11.1 lb. per 24 hr, respectively (Table 11). Data from the 14 cows milked later in their lactation indicated a less pronounced, downward trend of milk yield (Table 12).

The nature of the difference between dairy and range cow milk yield curves, as suggested by Gifford (1949, 1953), may be attributed to the effect of nursing. The milk yield of a range cow during the early stage of lactation would decline to the level of the calf's appetite, a physiologically irreversible phenomenon (Petersen and Rigor, 1932). In the present experiment, mean milk yield in June as estimated by calf consumption was 14.3 lb. per 24 hr and by the manual method was 16.9 lb.per 24 hr (Table 11). The correlation between results from the two methods was not high ($r=0.58$). A regression of pounds of milk consumed per day on age of calf from birth to 40 days of age ($b=0.042$) indicated that milk intake increased with age.

Table 10. Twenty-four hour and 180-day milk yield records for 42 cows

Cow identification[1,2]		24-Hr milk yield June	July	Aug	Oct	Avg	Calf consumption	180-Day yield
		lb.					lb.	lb.
CA	4-1	14.0	13.6	12.8	10.0	12.6	20	2203
	10-1	19.0	19.2	18.0	14.8	17.7	29	3142
	64-1	18.4	20.4	22.8	13.6	18.8	19	3292
	33-9	17.6	18.0	13.6	10.8	15.0	22	2666
	35-9	17.8	19.2	17.2	13.6	17.0	20	3071
	13-1	19.4	19.2	17.2	14.4	17.6	14	3040
	37-9	14.8	18.8	16.0	10.8	15.1	16	2699
	38-9	15.0	16.8	16.4	14.0	15.6	10	2770
AG	112-2	15.0	14.4	13.2	10.8	13.4	9	2361
(GA)	160-2	12.8	12.4	10.8	9.2	11.3	11	1943
	126-2	7.4	10.0	7.6	6.8	8.0	8	1410
	163-2	9.4	9.2	6.8	5.6	7.8	10	1369
	103-2	11.0	10.0	9.2	6.0	9.0	10	1663
H_2	29-2	7.4	9.6	8.4	6.8	8.0	8	1419
	25-2	7.4	10.4	8.4	9.2	8.8	10	1549
	34-2	6.6	7.2	5.6	4.4	6.0	6	1064
	30-2	10.6	10.8	11.2	7.2	10.0	9	1772
	44-2	8.8	9.4	8.2	6.4	8.2	9	1465
H	14-9	16.0	9.6	6.4	6.8	9.7	8	1678
	37-9	12.0	10.8	8.0	5.2	9.0	12	1613
	94-9	13.6	10.0	11.2	9.6	11.1	17	1999
	92-9	18.6	16.0	11.6	12.8	14.8	15	2519
	166-9	14.6	12.4	8.4	8.4	11.0	13	1997
	62-9	19.4	11.2	10.0	9.6	12.6	19	2147
	2-9	16.8	10.8	7.6	6.4	10.4	11	1769
	8-9	18.0	14.4	11.6	8.8	13.2	14	2382
G	2-8	22.6	23.2	18.0	16.4	20.0	14	3588
	23-8	21.6	17.2	15.6	9.6	16.0	12	2858
	5-8	22.2	16.4	16.8	11.6	16.8	9	2880
	1-8	24.2	22.0	18.4	13.6	19.6	19	3479
	12-8	22.0	18.0	14.8	11.4	16.6	16	3059
	49-8	17.0	16.8	14.0	12.6	15.1	14	2626
	24-8	23.0	19.2	15.2	13.2	17.6	18	3182
	48-8	20.4	19.6	14.0	10.0	16.0	11	2618
A	59-9	19.8	18.0	18.4	14.4	17.6	18	3143
	64-9	22.0	15.6	15.6	16.0	17.3	19	3086
	55-9	21.2	18.8	16.4	14.0	17.6	19	3156
	58-9	18.8	22.0	16.7	15.2	18.2	16	3259
	51-9	19.8	19.2	15.6	15.4	17.5	6	3105
	50-9	25.0	23.6	18.0	17.2	22.0	17	3659
	61-9	21.8	17.2	16.8	17.2	18.2	19	3308
	65-9	26.6	22.0	16.0	16.4	20.2	24	3621

[1] CA, Charolais x Angus; AG (GA), Angus x Galloway; H_2, Hereford heifer; H, mature Hereford; G, Galloway; A, Angus.

[2] -8, born 1958; -9, born 1959; -1, born 1961; -2, born 1962.

Table 11. Twenty-four-hour and 180-day milk yield means, standard deviations, and regression coefficients of daily milk yield on day of lactation

Breed of cow	Recording (lb.) June	July	Aug	Oct	Total	June consumption (4-day)	180 days
Charolais x Angus							
Mean	17.0	18.2	16.8	12.8	16.2	18.8	2861
SD	2.09	2.12	3.04	1.89	3.02	5.68	347.6
b[1]					-.035		
SE[1]					(.0190)		
Angus x Galloway							
Mean	11.1	11.2	9.5	7.7	9.9	9.6	1749
SD	2.94	2.15	2.57	2.23	2.72	1.14	411.8
b					-.033		
SE					(.0162)		
Hereford (2-yr-old)							
Mean	8.2	9.5	8.4	6.8	8.2	8.4	1458
SD	1.58	1.40	1.98	1.72	1.83	1.52	259.9
b					-.014		
SE					(.0114)		
Hereford (mature)							
Mean	16.1	11.9	9.3	8.4	11.4	13.6	2013
SD	2.58	2.24	2.02	2.36	3.73	3.46	325.6
b					-.062**		
SE					(.0161)		
Galloway							
Mean	21.6	19.0	15.8	12.3	17.2	14.1	3036
SD	2.16	2.47	1.71	2.18	4.09	3.44	360.9
b					-.069**		
SE					(.0217)		
Angus							
Mean	21.9	19.6	16.7	15.7	18.5	17.2	3292
SD	2.69	2.74	1.04	1.19	3.16	5.12	227.6
b					-.052*		
SE					(.0204)		
Total							
Mean	16.9	15.5	13.3	11.1	14.2	14.3	2515
SD	5.26	4.56	4.19	3.66	4.42	5.20	721.7
b					-.047**	.042	
SE					(.0079)	(.0340)	

[1]b - regression coefficient; SE - standard error of regression.

*Significant at $P<0.05$.

**Significant at $P<0.01$.

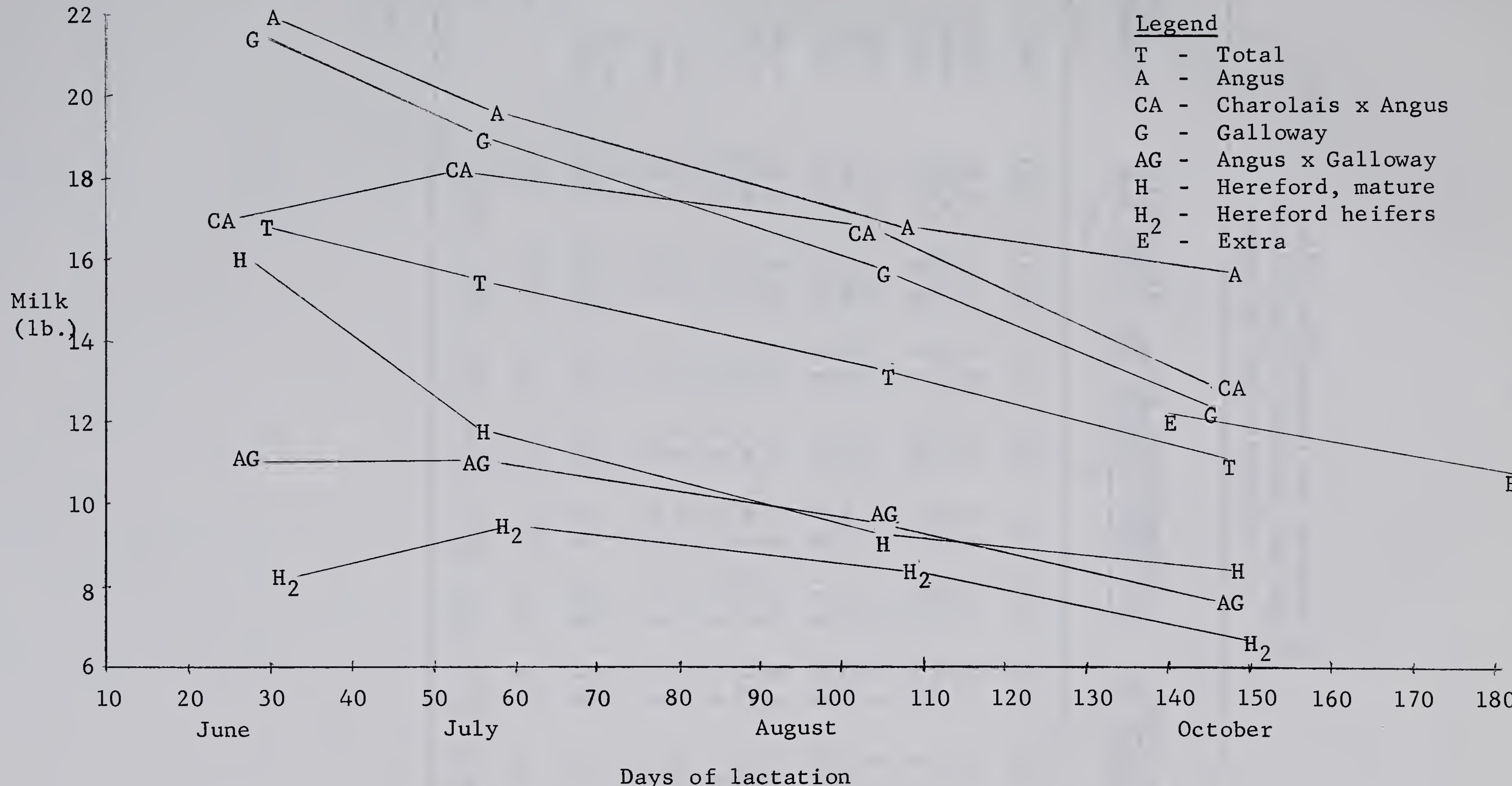

Fig. 2. Breed-age group and experimental herd 24-hour milk production plotted against the average lactation day for each recording.

Table 12. Milk yield-composition records of additional 14 cows for the last 2 months of their lactation

Cow identification		24-Hr milk		Aug constituents				Oct constituents			
		Aug	Oct	BF[1]	Protein	SNF	TS	BF	Protein	SNF	TS
		lb.		%				%			
CA	34-9	19.6	16.0	3.3	3.6	9.0	12.3	4.0	3.7	9.4	13.4
AG	153-2	8.0	7.2	3.8	3.3	8.9	12.7	4.5	3.7	9.3	13.8
(GA)	106-2	12.0	10.4	3.3	3.3	8.8	12.1	4.0	3.4	9.0	13.0
	128-2	9.2	8.8	3.4	3.8	9.6	13.0	4.4	3.1	8.6	13.0
H_2	15-2	7.2	7.2	4.2	3.3	9.1	13.3	3.6	3.5	9.5	13.1
	20-2	6.0	6.4	3.8	3.5	9.2	13.0	3.8	3.5	9.2	13.0
	2-2	8.0	6.0	3.6	3.2	8.6	12.2	3.9	3.4	8.6	12.5
H	184-9	13.2	8.8	3.9	3.4	9.3	13.2	4.8	3.7	9.4	14.2
	19-9	12.8	12.0	4.0	3.4	9.3	13.3	3.5	3.6	9.0	12.5
	107-9	11.2	8.0	4.0	3.6	9.1	13.1	5.4	3.8	9.3	14.7
G	20-8	12.4	14.8	5.0	3.8	9.4	14.4	4.1	3.4	8.9	13.0
	18-8	12.4	11.2	3.6	3.8	9.7	13.3	3.8	3.2	9.5	13.3
A	54-9	15.2	15.2	3.8	3.6	9.1	12.9	4.1	3.5	9.1	13.2
	53-9	17.2	14.4	4.3	3.7	9.5	13.8	3.8	3.5	9.5	13.3
Mean		11.7	10.4	3.8	3.5	9.2	13.1	4.1	3.5	9.2	13.3
SD		3.88	3.50	0.45	0.20	0.32	0.61	0.51	0.20	0.32	0.61

[1]Butterfat.

However, a calf's appetite as a limitation in the earliest part of lactation could influence the the nature of milk yield trends.

Two breed groups demonstrated consumption records higher than (Charolais x Angus) or equal to (Hereford heifers) records obtained by milking, in contrast to other breed-age groups. The phenomenon was reflected in milk yield trends (Fig. 2) where milk yield rose from June to July for Charolais x Angus and Hereford heifers, in contrast to other groups for which milk yield declined or remained constant. The milk yield of heifer groups, however, appeared too low at any time to be restricted by calf appetite.

The accuracy of milk yield estimation by calf consumption was subject to error because urination, defecation, and robbing of milk could not be accounted for. Many calves suffered diarrhea, probably a result of upsets caused by handling and confining. The calves not consuming milk at a level near the milk yield of their dams in June, when retested in July were found to do so.

B. Milk composition and lactation trends

Individual milk constituent records ranged from 2.8 to 4.7%, 3.0 to 4.8%, 8.8 to 9.6%, and 11.8 to 13.9% for butterfat, protein, SNF, and TS, respectively (Table 13). Season averages for the breed groups ranged from 3.6 to 4.0% for butterfat, 3.4 to 3.8% for protein, 12.7 to 13.1% for TS, and 9.0 to 9.2% for SNF (Table 14). Season averages for the 42 cows were 3.9, 3.5, 13.0, and 9.1% for butterfat, protein, TS, and SNF, respectively. Seasonal fluctuations for the experimental herd were small for protein (3.4 to 3.5%) and SNF (9.0 to 9.2%). Variation over the season was greater for TS (12.8 to 13.6%) and for butterfat (3.6 to 4.4%).

Table 13. Milk composition averages for 42 cows

Cow identification		Constituent percentages			
		BF	Protein	SNF	TS
CA	4-1	3.8	3.6	9.0	12.7
	10-1	3.5	3.3	9.1	12.6
	64-1	4.3	3.4	9.0	13.3
	33-9	3.9	3.3	9.2	13.0
	35-9	3.5	3.5	9.6	13.0
	13-1	3.1	3.8	9.2	12.3
	37-9	3.9	3.5	9.2	13.1
	38-9	4.0	3.5	9.2	13.2
AG	112-2	3.8	3.6	8.9	12.7
(GA)	160-2	3.8	3.5	9.1	12.9
	126-2	4.0	3.4	9.0	13.0
	163-2	3.8	3.4	9.1	12.9
	103-2	3.7	3.3	8.9	12.6
H_2	29-2	3.8	3.6	9.3	13.1
	25-2	2.8	3.4	9.1	11.8
	34-2	3.8	3.8	9.3	13.1
	30-2	3.7	3.2	8.8	12.5
	44-2	3.8	4.8	9.3	13.1
H	14-9	4.7	3.4	8.8	13.9
	37-9	3.6	3.5	9.0	12.6
	94-9	3.5	3.3	9.1	12.6
	92-9	4.0	3.3	9.1	13.1
	166-9	3.8	3.6	9.3	13.2
	62-9	3.9	3.3	9.0	13.0
	2-9	3.7	3.4	9.2	13.0
	8-9	4.2	3.4	9.0	13.2
G	2-8	3.7	3.4	9.0	12.7
	23-8	4.0	3.3	9.0	12.9
	5-8	4.5	3.6	9.2	13.7
	1-8	3.8	3.0	9.0	12.8
	12-8	4.1	3.4	9.0	13.1
	49-8	3.7	3.4	9.4	13.1
	24-8	3.8	3.2	8.8	12.6
	48-8	3.9	3.5	9.3	13.1
A	59-9	3.9	3.7	9.2	13.2
	64-9	4.0	3.5	9.1	13.1
	55-9	3.6	3.5	9.1	12.7
	58-9	4.7	3.2	8.9	13.6
	51-9	3.9	3.4	9.1	12.9
	50-9	3.8	3.3	9.2	12.9
	61-9	4.6	3.4	9.0	13.6
	65-9	3.9	3.5	9.2	13.1

Table 14. Means and standard deviations of milk composition for breed-age groups and experimental herd

Recording	Charolais x Angus		Angus x Galloway		Hereford (2-yr-old)		Hereford (mature)		Galloway		Angus		Total	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
June														
BF	3.8	0.71	3.7	0.29	3.3	1.37	3.6	0.48	3.5	0.48	3.9	0.46	3.6	0.66
Protein	3.4	0.31	3.3	0.16	3.6	0.46	3.5	0.13	3.3	0.27	3.4	0.24	3.4	0.27
SNF	9.2	0.34	9.1	0.22	9.3	0.44	9.2	0.25	9.2	0.28	9.2	0.27	9.2	0.29
TS	13.0	0.64	12.8	0.32	12.6	1.37	12.8	0.48	12.6	0.68	13.1	0.38	12.8	0.66
July														
BF	3.6	0.46	3.5	0.25	3.5	0.46	4.0	0.78	3.8	0.49	4.1	0.64	3.8	0.58
Protein	3.5	0.17	3.4	0.24	3.4	0.21	3.3	0.17	3.2	0.18	3.4	0.20	3.4	0.20
SNF	9.4	0.42	8.9	0.16	8.9	0.26	8.7	0.57	8.9	0.17	9.0	0.14	9.0	0.39
TS	12.9	0.50	12.4	0.19	12.4	0.38	12.8	0.27	12.7	0.54	13.1	0.57	12.8	0.50
August														
BF	3.6	0.40	4.0	0.11	3.7	0.50	4.0	0.42	4.0	0.40	3.9	0.54	3.9	0.43
Protein	3.6	0.15	3.6	0.18	3.5	0.37	3.5	0.33	3.6	0.19	3.5	0.16	3.5	0.23
SNF	9.0	0.18	8.9	0.21	9.1	0.59	9.1	0.40	9.2	0.27	9.0	0.17	9.1	0.31
TS	12.7	0.46	12.8	0.30	12.8	0.69	13.1	0.73	13.1	0.50	12.9	0.57	12.9	0.56
October														
BF	4.0	0.54	4.4	0.43	3.9	0.33	4.5	0.46	4.9	0.83	4.3	0.58	4.4	0.64
Protein	3.5	0.25	3.4	0.12	3.6	0.25	3.3	0.10	3.4	0.24	3.4	0.27	3.4	0.23
SNF	9.2	0.34	9.1	0.29	9.5	0.47	9.2	0.23	9.2	0.33	9.2	0.18	9.2	0.31
TS	13.2	0.72	13.5	0.57	13.4	0.76	13.7	0.64	14.1	1.00	13.5	0.55	13.6	0.75
Total														
BF	3.7	0.37	3.8	0.11	3.6	0.46	3.9	0.39	4.0	0.28	4.0	0.38	3.9	0.36
Protein	3.5	0.15	3.4	0.10	3.8	0.60	3.4	0.10	3.4	0.17	3.4	0.15	3.5	0.25
SNF	9.2	0.19	9.0	0.13	9.1	0.25	9.0	0.17	9.1	0.21	9.1	0.12	9.1	0.18
TS	12.9	0.34	12.8	0.19	12.7	0.58	13.0	0.31	13.0	0.34	13.1	0.32	13.0	0.36

The lactation trends in chemical composition of milk were similar to those reported for dairy cows by Waite et al., (1956) but different from those reported by Longley and Rennie (1964). Percentages of protein, SNF, and TS decreased to a low reading in July and then increased (Fig. 3). Butterfat percentage increased from the beginning with a very sharp further increase from the August to the October recordings. Data from the 14 cows milked later in their lactation showed that percentages of protein and SNF were decreasing, and butterfat and TS increasing (Fig. 3). Breed-age groups followed herd trends with few exceptions.

C. Factors related to milk yield and composition

The sum of the four 24-hr recordings was very highly correlated with any individual or adjacent combination of recordings (r=0.91 to 1.00). Therefore, the sum of the four recordings was used in determining the relation of certain factors to milk yield.

The effect of breed of sire and calf could not be isolated due to confounding. Also, due to confounding of breed of dam with age of dam, only the three groups composed entirely of mature cows could be included in estimating effects of breed. The breeds involved were Hereford, Angus, and Galloway. By analysis of variance, the effect of breed of dam on milk yield was found to be highly significant (Table 15), the component of variance being 74.5%. There was no influence of sex of calf on milk yield of dam as shown by analysis of variance.

The relationship of milk yield and composition to other factors was estimated from correlation coefficients. There was a low, negative correlation between cow weight change and milk yield (r=-.41) and with ADG of calf (r=-.45). The cows milking more lost more weight over the summer and produced faster-growing calves.

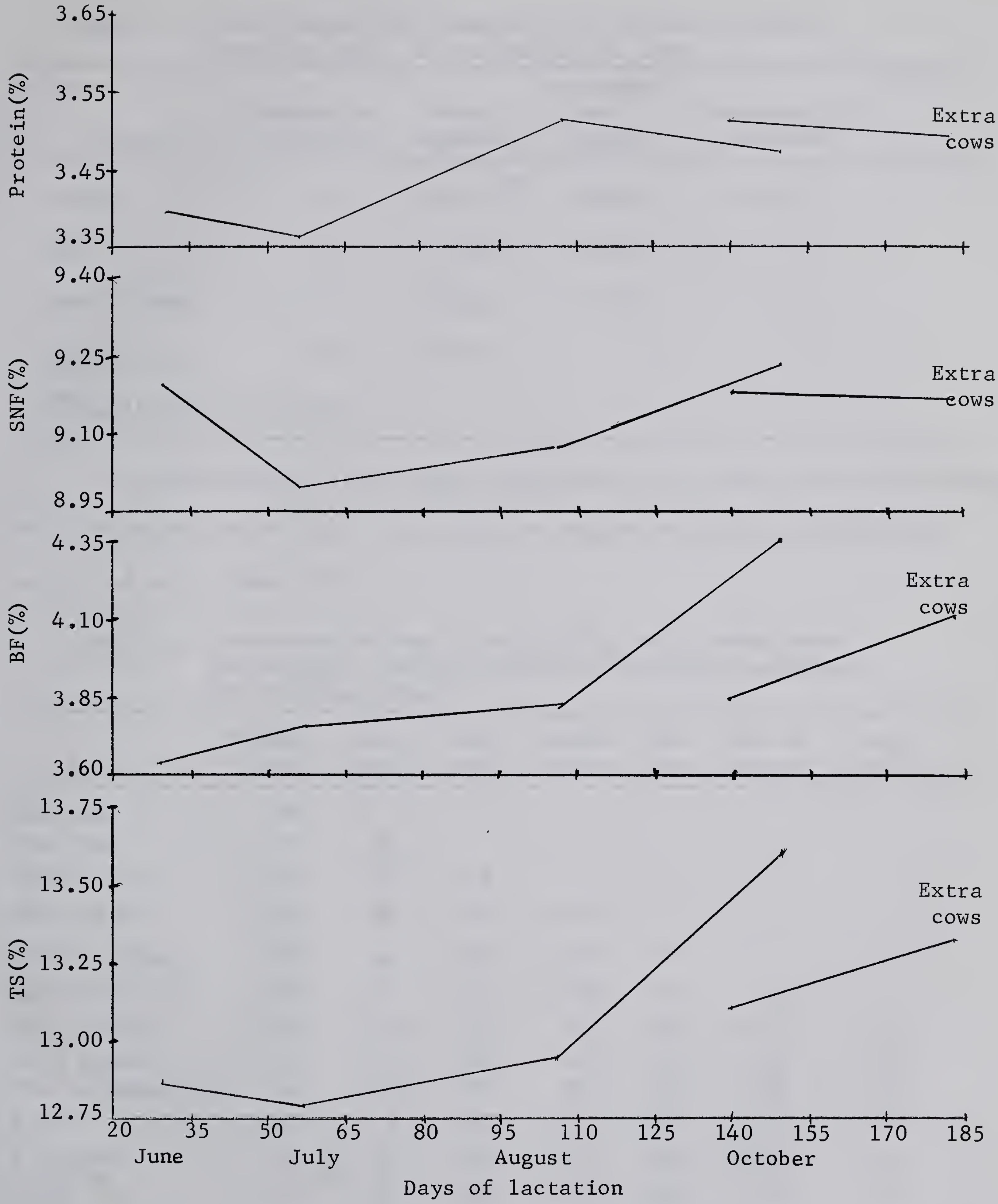

Fig. 3. Experimental herd milk constituent percentages plotted against the average lactation day for each recording.

Table 15. Mean squares and components of variance of milk yield by breed of dam and sex of calf

Source	Degrees of freedom	Mean squares	Estimated mean squares	Component of variance
Breed	2	1785.10**	188.07	74.5%
Sex	1	7.82	-22.81	
Breed x sex	2	58.39	17.44	
Error	18	47.00		

**Significant at $P < 0.01$.

No statistically significant correlations ($P < 0.05$) were found between milk yield and sex of calf, test day, cow weight, milking ease, or birth weight of calf (Table 16).

Table 16. Intercorrelations of milk yield, milk constituent percentages, and some other cow and calf variables for 24 mature cows

Factor	Milking ease	Calf sex	Test day	March cow wt	Oct cow wt	Cow wt change	Calf birth wt
Calf sex	.09						
Test day	.21	.06					
March cow wt	-.23	-.12	.18				
Oct cow wt	-.28	.01	.14	.87			
Cow wt change	-.08	.26	-.08	-.32	.18		
Calf birth wt	-.18	-.21	-.39	.08	.12	.08	
Milk yield	.13	-.04	.10	.03	-.19	-.41	-.34
Calf growth	.04	-.24	.21	.25	.03	-.45	-.18
Milk consumption	.34	.08	.27	.06	.02	-.08	-.34
% BF	.36	.10	.11	-.18	-.22	-.07	-.06
% Protein	.06	.22	-.10	.13	.24	.20	-.15
% SNF	-.06	.07	-.41	-.33	-.24	.19	-.23
% TS	.35	.16	-.07	-.32	-.31	.03	-.16

$r = 0.40$ significant at $P < 0.05$

$r = 0.50$ significant at $P < 0.01$

No statistically significant correlations ($P < 0.05$) of independent variables with the constituents of milk were found, with the exception of that between test day and per cent SNF (r=0.41). The significance of that correlation loses importance in the light of the very slight variation in per cent SNF over the lactation period.

D. Relation of calf growth to milk yield

The correlation between ADG and 180-day weight was 0.99, therefore ADG will be used throughout this thesis as a measure of calf growth.

The birth weight of experimental calves was 78 lb. and ADG to weaning was 1.77 lb. per day compared to 79 lb. and 1.78 lb. per day for all calves born on the ranch in 1964 (Table 17). Weights and gains were uncorrected for sex of calf and age of dam. Table 17 shows that, for birth weight and ADG, breed-age samples were representative of breed-age groups on the ranch.

Ranking of dam breed-age groups by calf growth was very near the ranking according to milk yield (Fig. 2, p. 32 and Fig. 4). Calves from Charolais x Angus and Angus cows had the highest averages, followed consecutively by those from Galloway, mature Hereford, Angus x Galloway, and Hereford heifers.

Although it might be expected that a within-sex correlation between milk yield and ADG would be higher than a total correlation, the correlations involving female and male calves were similar in magnitude to the total correlation (r=0.85, 0.87, and 0.85, respectively).

When correlations were calculated between individual milk recordings and the respective ADG immediately preceding them, changes were noted over the lactation period (r=0.62, 0.75, 0.56, and 0.51 for successive recordings) (Table 18). Generally a close relationship between milk yield and ADG was found to exist, as shown by correlations within longer periods from

Table 17. Progeny records of cows -- means and standard deviations

Breed of cow	Birth wt, lb.	ADG, lb. Birth-June	Birth-July	Birth-Aug	June-July	July-Aug	Aug-Oct	Total	Ranch herd Birth wt, lb.	ADG, lb.
CA										
Mean	80.8	1.88	2.07	2.06	2.19	2.02	2.09	2.07	82.0	2.07
SD	12.92	0.249	0.250	0.184	0.284	0.181	0.365	0.224		
AG (GA)										
Mean	72.2	1.12	1.32	1.42	1.44	1.81	1.61	1.48	71.0	1.60
SD	4.76	0.181	0.131	0.156	0.074	0.493	0.396	0.197		
H_2										
Mean	68.2	1.03	1.16	1.13	1.39	0.95	1.54	1.25	67.0	1.35
SD	7.95	0.628	0.130	0.154	0.338	0.376	0.305	0.176		
H										
Mean	85.6	1.44	1.55	1.44	1.65	1.46	1.94	1.56	84.0	1.61
SD	9.07	0.256	0.213	0.327	0.248	0.375	0.482	0.197		
G										
Mean	77.1	1.65	1.85	1.87	1.93	1.96	1.97	1.91	81.0	1.88
SD	3.98	0.434	0.236	0.215	0.221	0.418	0.255	0.195		
A										
Mean	75.5	1.75	1.97	2.00	2.11	2.11	2.20	2.07	81.0	1.88
SD	18.90	0.215	0.090	0.102	0.176	0.465	0.251	0.141		
Total										
Mean	77.5	1.53	1.71	1.71	1.84	1.77	1.94	1.77	79.0	1.78
SD	12.01	0.438	0.368	0.386	0.374	0.526	0.399	0.351		

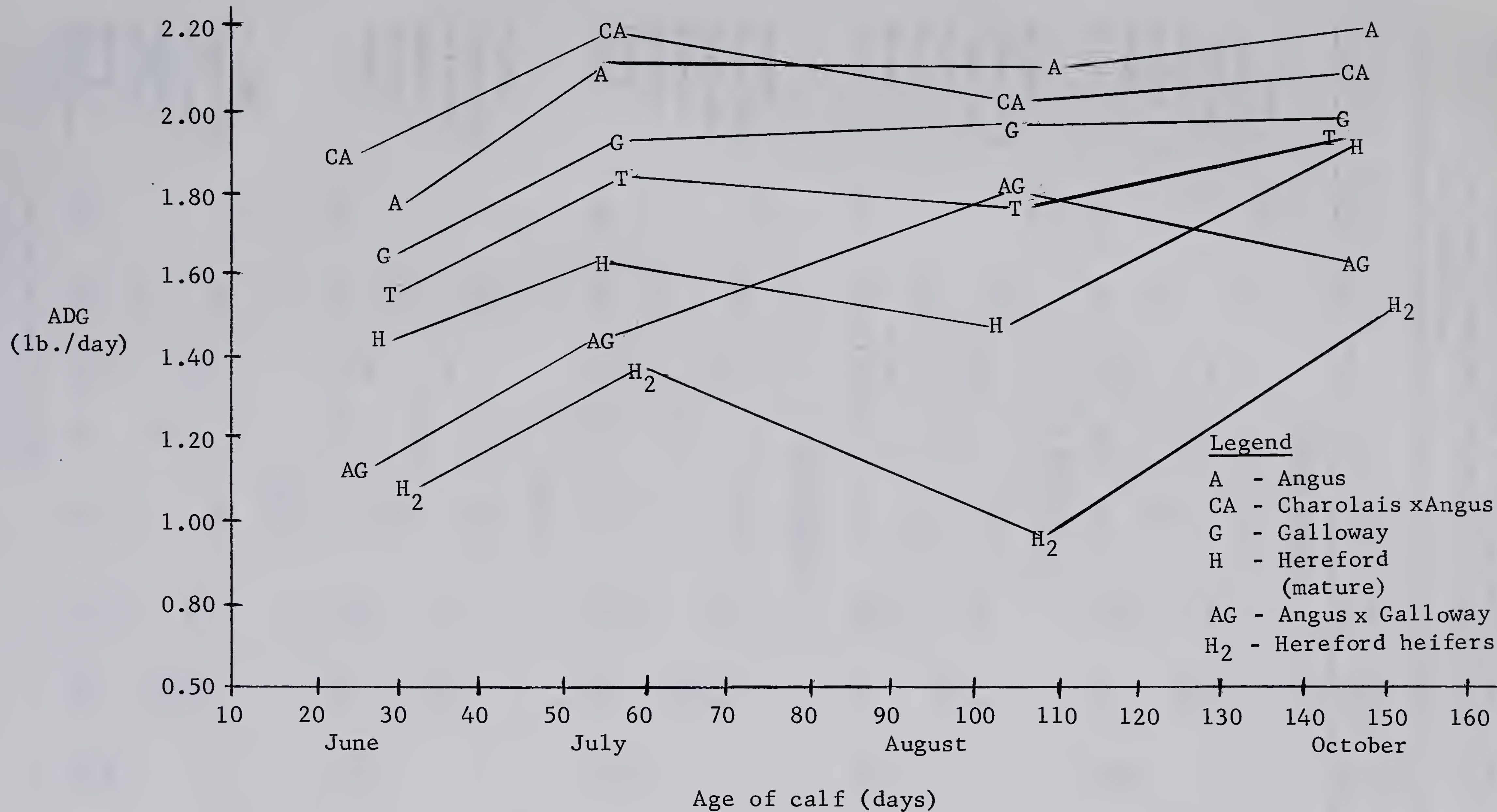

Fig. 4. Average daily gain of calves by four periods according to the average lactation day for each recording, for breed-age groups and experimental herd.

Table 18. Correlation of milk yield and milk constituent percentages to calf gain for individual, cumulative, and total periods of lactation

ADG	June	July	Aug	Oct	June+ July	July+ Aug	Aug+ Oct	June+ July+ Aug	July+ Aug+ Oct	Total
					Milk yield					
B[1]-June	.62									
June-July		.75			.71					
July-Aug			.56			.62	.61		.63	
Aug-Oct				.51			.49		.50	
B-July		.81			.80					
B-Aug			.83			.84		.84		
B-Oct	.73	.83	.81	.82	.81	.84	.84	.84	.85	.85
					% Butterfat					
B-June	.08									
June-July		.02			.03					
July-Aug			.05			.06	.14		.13	
Aug-Oct				-.21			-.26		-.24	
B-July		.10			.10					
B-Aug			-.14			.05		.10		
B-Oct	.05	.05	-.18	-.07	.07	-.04	-.16	.01	-.05	-.01
					% Protein					
B-June	-.09									
June-July		-.09			-.32					
July-Aug			.17			.09	.02		.13	
Aug-Oct				-.11			.05		.10	
B-July		-.13			-.28					
B-Aug			-.12			-.14		-.24		
B-Oct	-.40	-.04	-.01	-.17	-.27	-.02	-.09	-.19	.01	-.30
					% SNF					
B-June	.03									
June-July		.45			.24					
July-Aug			.04			.27	-.04		.16	
Aug-Oct				-.25			-.16		.20	
B-July		.40			.25					
B-Aug			-.16			.23		.09		
B-Oct	-.16	.40	-.14	-.27	.22	.32	-.21	.16	.16	.06
					% TS					
B-June	.11									
June-July		.36			.16					
July-Aug			.07			.22	.09		.20	
Aug-Oct				-.28			-.30		-.16	
B-July		.41			.23					
B-Aug			-.19			.17		.09		
B-Oct	-.02	.40	-.21	-.18	.19	.13	-.24	.04	.00	.01

[1] Birth

r = 0.30 significant at $P < 0.05$

r = 0.39 significant at $P < 0.01$

birth or when a single milk recording was correlated to ADG from birth to weaning (r=0.81 to 0.85 with few exceptions). These relationships agree with those found by Brumby et al. (1963), Neville (1962), Walker (1963), Gifford (1953), and Anthony et al. (1959) although some of the authors used the calf-suckling and others the manual method of estimating milk yield.

The reason for the lower relationship between milk yield and ADG in the 1st month may have been because milk yield was in excess of calf requirements. By the 2nd month, the calf was still heavily dependent upon milk as a source of energy and was able to consume all milk available, with a resultant increase in correlation between milk yield and ADG. The declining relationship between calf growth and milk yield to the 3rd and 5th months indicated a decreasing dependency upon milk for energy.

E. <u>Relation of calf growth to milk constituent percentages</u>

Correlations of calf growth to butterfat or protein percentages were mainly negative but non-significant (Table 18). There were also some non-significant negative correlations between SNF or TS percentages and calf growth in addition to significant, but low, positive correlations. Klett et al. (1965) also reported non-significant correlations between milk constituent percentages and calf gain.

Multiple regressions of milk yield and constituent percentages on calf growth were calculated where independent variables were entered in the order shown in Table 19. In all cases, after variation in ADG due to milk yield was removed, very little more could be accounted for by percentages of solids.

The significant contribution of per cent TS to calf gain, after variation due to butterfat and SNF percentages was removed, cannot be

Table 19. Ordered regression of average daily gain on milk yield and milk constituent percentages for individual, cumulative, and total periods of lactation

ADG	Regression coefficient	Standard error	Coefficient determination	Constant
B[1]-June				
June milk	0.051**	0.0120	38.84	-1.034
Butterfat	-0.056	2.1825	0.02	
Protein	-0.038	0.3542	0.54	
SNF	0.109	2.1536	0.53	
TS	0.081	2.2027	0	
			39.94	
June-July				
July milk	0.053**	0.0099	55.89	-2.151
Butterfat	-0.689	1.0646	0.66	
Protein	-0.028	0.2017	0.06	
SNF	-0.463**	1.0676	6.64	
TS	0.785	1.0492	0.57	
			63.22	
July-Aug				
Aug milk	0.073**	0.0165	31.69	-3.275
Butterfat	-4.828	2.4962	0.97	
Protein	0.489*	0.3905	5.08	
SNF	-4.778	2.5020	0.37	
TS	4.974**	2.5114	6.08	
			44.19	
Aug-Oct				
Oct milk	0.055**	0.0151	26.33	3.300
Butterfat	0.976*	1.9119	6.31	
Protein	-0.013	0.2666	0.25	
SNF	0.992	1.9380	0.87	
TS	-1.129	1.9244	0.63	
			34.38	
Total				
Total milk	0.018**	0.0020	71.57	2.018
Butterfat	0.149*	1.3158	2.72	
Protein	-0.071	0.1413	0.31	
SNF	0.282	1.2271	0	
TS	-0.322	1.3392	0.04	
			74.64	

[1]Birth

*Significant at P <0.05.

**Significant at P <0.01.

explained biologically. Since per cent TS is composed solely of butterfat and SNF, per cent SNF having been arrived at by subtraction, there is no apparent reason for the additional effect due to TS after effect due to butterfat and SNF was removed other than that it may be an interaction effect between components of TS not accounted for individually. Perhaps contribution of any milk constituent percentage to calf growth is to be viewed with suspicion since none was above 7.0%.

F. Optimum recording of milk yield and constituents

1) Milk yield

Correlation of individual recordings of milk yield to the total was very high (r=0.91 to 0.98, Table 20). Intercorrelations of single recordings were high (r=0.75 to 0.90). Therefore any one estimate of milk yield would have been a suitable indication of lactating ability. The correlations of adjacent pairs and triplets of milk recordings with the total, although higher, were not significantly greater than correlations of single measurements with the total (Table 20).

June milk consumption had a medium correlation with June milking (r=0.58, Table 20) and with the total of the recordings (r=0.62), therefore calf consumption as measured here could not be considered an accurate measure of milk yield.

2) Milk constituents

Single measurements of constituents were lowly to mediumly correlated with the respective averages of the four testings (r=0.32 to 0.78, Table 20). Intercorrelations of single recordings were generally very low or non-significant (r=0.03 to 0.57). Although correlations were low, protein and SNF varied little over the season and therefore any one measurement would have been predictive of the whole. Combining adjacent pairs and triplets

of recordings increased the accuracy of prediction of over-all averages. However, it is reasonable to expect that averages of an increasing proportion of the whole would, accordingly, more accurately represent the whole.

3) Relationship of milk yield to ADG

Using correlations to over-all ADG as a criterion, any single estimate of ADG variation provided by milk yield was equal to any other single or adjacent combination estimate (r=0.81 to 0.85, Table 18) with the exception of the June recording (r=0.73). As discussed previously and shown in Table 20, per cent constituents made only a slight or non-significant contribution to calf growth.

Table 20. Intercorrelations of milk yield and milk constituent percentages for individual, cumulative, and total periods of lactation

	June	July	Aug	Oct	June+ July	July+ Aug	Aug+ Oct	June+ July+ Aug	July+ Aug+ Oct
				Milk yield					
July	.83								
Aug	.75	.90							
Oct	.79	.87	.87						
Total	.91	.96	.93	.93	.98	.97	.97	1.00	.98
June consumption[1]	.58								
				% Butterfat					
July	.24								
Aug	.11	.34							
Oct	.08	.42	.28						
Total	.65	.78	.54	.61	.89	.82	.73	.94	.87
				% Protein					
July	.27								
Aug	.06	.52							
Oct	.28	.36	.33						
Total	.32	.39	.45	.66	.45	.50	.66	.56	.49
				% SNF					
July	.09								
Aug	.16	-.26							
Oct	.14	-.19	.57						
Total	.61	.52	.50	.50	.77	.82	.59	.94	.90
				% TS					
July	.27								
Aug	.09	.07							
Oct	.03	.26	.39						
Total	.65	.69	.53	.61	.82	.82	.68	.92	.86

[1]Correlation with total ADG = 0.62.

r = 0.30 significant at $P < 0.05$
r = 0.39 significant at $P < 0.01$

SUMMARY AND CONCLUSIONS

Eight each of mature Hereford, Galloway, and Angus; eight Charolais x Angus (four 3-year olds and four 5-year olds); and five each of 2-year-old Hereford and Angus x Galloway cows were milked to determine the following: the levels and lactation trends of milk yield and milk composition, the relation of various factors to milk yield, the effect of milk yield and composition on calf growth, and the optimum procedure for recording of milk yield and milk constituents. Fourteen additional cows, which calved 1 month earlier than the original 42 cows and which were distributed over the same breed-age groups, were also tested to estimate the persistency of lactation trends. The 42 cows were tested four times during their lactation and the 14 cows were tested twice.

Milking was done by machine with the use of oxytocin to stimulate milk let-down. Twenty-four-hr milk yield was estimated from the 12-hr yield of one-half of the udder. Milk was analyzed for butterfat, protein, SNF, and TS. Calf milk consumption was measured in the 1st month.

Breed-age group averages for 24-hr milk yield ranged from 8.2 to 18.5 lb. and the herd average was 14.2 lb. The range of individual lactation averages was 6.0 to 22.0 lb. Herd mean milk yields at successive recordings declined from 16.9, 15.5, 13.3, to 11.1 lb. for the 1st, 2nd, 3rd, and 5th months, respectively. Data from the 14 cows milked later in their lactation period indicated a slight levelling off of the decrease in milk yield. The linear decline of milk yield did not follow dairy cow trends where a normal peak is reported to occur at 45 days of lactation. The reason for the difference may be attributed to calf suckling.

Average calf milk consumption measured in June was 14.3 lb. Calf consumption was lowly correlated to milk yield estimated by manual methods

in the same month (r=0.58) and therefore was not a good estimate of milk yield at that time. A regression of milk consumed on age of calf to 40 days of age indicated that milk intake increased with age of calf (b=0.042). Range cow milk yield in the early stages of lactation generally exceeds calf consumption, thus restricting milk yield. Two breed-age groups, which demonstrated calf milk consumption as great as dam milk yield, had milk yield curves which rose from the 1st to the 2nd months, unlike the milk yield curves of the other groups. Heifer milk yield curves changed very little, probably because production was never high enough to be restricted by calf appetite.

The chemical composition of milk followed dairy cow trends. Protein, SNF, and TS percentages decreased to the 2nd month and then increased. Butterfat percentage increased from the beginning, very sharply from the 3rd to the 5th months. Lactation averages were 3.9, 3.5, 9.1, and 13.0% for butterfat, protein, SNF, and TS, respectively. Milk constituent percentages varied little over the lactation period (3.6 to 4.4%, 3.4 to 3.5%, 9.0 to 9.2%, and 12.8 to 13.6% for butterfat, protein, SNF, and TS, respectively). Data from the 14 cows milked later in their lactation indicated a continuation in the rise of butterfat and TS percentages and leveling off in the rise of protein and SNF percentages.

An analysis of variance with 24 mature cows (Hereford, Angus, and Galloway) revealed that variation in the breed of dam contributed significantly ($P < 0.01$) to variation in milk yield and that variation in sex of calf did not significantly affect milk yield. The component of variance for breed of dam was 74.5%.

There was a low, negative correlation of cow weight change over the summer with milk yield (r=-.41) and with calf gain (r=-.45) indicating that

the cows with the highest milk yield and producing the heaviest calves tended to lose the most weight over the summer.

Day of lactation at first test, milking ease, cow weight, and sex and birth weight of calf were not found to be significantly correlated to milk yield or constituent percentages.

Intercorrelations of single and total of milk yield recordings were very high (r=0.75 to 0.96). Therefore, any one estimate of milk yield would have been a suitable indication of lactating ability. Similar correlations for respective constituent percentages were low; however, since there was little variation over the season, one recording would have been sufficiently predictive of the whole lactation.

Correlation coefficients for ADG with milk yield within the 1st, 2nd, 3rd, and 5th months were 0.63, 0.75, 0.56, and 0.52, respectively. Correlations of any single milk recording or combination of recordings with ADG from birth to weaning were high (r=0.81 to 0.85 with one exception), therefore, any one milk yield estimate could be considered highly predictive of variation in calf growth. The low relationship between ADG and milk yield in the 1st month of lactation could be attributed to milk yield exceeding calf appetite. The higher relationship in the 2nd month reflected a combination of high milk production, a high degree of calf dependency upon milk for energy, and the ability of the calf to consume more milk. The decreased relationship in late lactation demonstrated a decreasing dependency by the calf upon milk for energy, combined with a decreased milk yield of the dam.

The correlations between ADG and milk constituent percentages were generally low and non-significant.

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Table A. Progeny records of cows

Cow identification		Birth wt (lb.)	ADG (lb.) Birth-June	June-July	July-Aug	Aug-Oct	Total
CA	4-1	73	1.63	1.87	2.14	1.93	1.89
	10-1	105	2.15	2.80	1.90	2.73	2.52
	64-1	77	1.81	2.17	2.38	1.59	1.95
	33-9	86	2.29	2.20	1.90	2.39	2.23
	35-9	89	1.80	2.17	1.90	2.04	1.99
	13-1	67	1.73	1.89	1.90	1.71	1.81
	37-9	66	1.59	2.22	2.14	2.16	2.03
	38-9	83	2.00	2.20	1.90	2.16	2.11
AG	112-2	72	1.32	1.54	1.90	2.27	1.78
(GA)	160-2	75	1.31	1.48	1.43	1.59	1.49
	126-2	64	0.97	1.37	1.43	1.25	1.26
	163-2	75	1.06	1.46	2.62	1.36	1.50
	103-2	75	0.95	1.37	1.67	1.59	1.35
H_2	29-2	82	2.10	0.91	1.43	1.36	1.26
	25-2	67	0.94	1.80	0.95	2.04	1.48
	34-2	64	0.57	1.30	0.48	1.25	0.99
	30-2	62	0.97	1.35	0.71	1.48	1.21
	44-2	66	0.57	1.61	1.19	1.59	1.29
H	14-9	91	1.33	1.37	1.43	1.25	1.33
	37-9	89	1.20	1.61	0.95	2.16	1.51
	94-9	85	1.48	1.98	1.19	2.27	1.84
	92-9	90	1.62	1.50	1.67	1.48	1.53
	166-9	66	0.95	1.52	2.16	2.61	1.31
	62-9	95	1.60	1.96	1.67	2.27	1.73
	2-9	89	1.68	1.39	1.43	1.48	1.48
	8-9	80	1.62	1.85	1.19	2.04	1.76
G	2-8	81	1.80	2.26	2.86	2.04	2.17
	23-8	83	2.00	1.83	2.14	1.93	1.94
	5-8	78	1.04	1.61	1.90	1.48	1.52
	1-8	75	2.06	2.22	1.43	1.82	1.94
	12-8	72	2.02	1.98	1.90	2.27	2.06
	49-8	72	1.12	1.93	1.90	1.93	1.82
	24-8	77	1.89	1.85	1.90	2.27	1.99
	48-8	79	1.25	1.76	1.67	2.04	1.80
A	59-9	81	1.76	2.24	1.67	2.39	2.10
	64-9	93	1.89	2.09	1.67	1.93	1.93
	55-9	73	1.94	2.09	1.43	2.39	2.05
	58-9	76	1.65	2.13	2.14	1.82	1.91
	51-9	77	1.70	2.00	2.62	2.50	2.27
	50-9	100	1.48	2.41	2.62	2.39	2.28
	61-9	67	1.49	2.13	2.38	2.04	1.98
	65-9	37	2.09	1.80	2.38	2.16	2.06